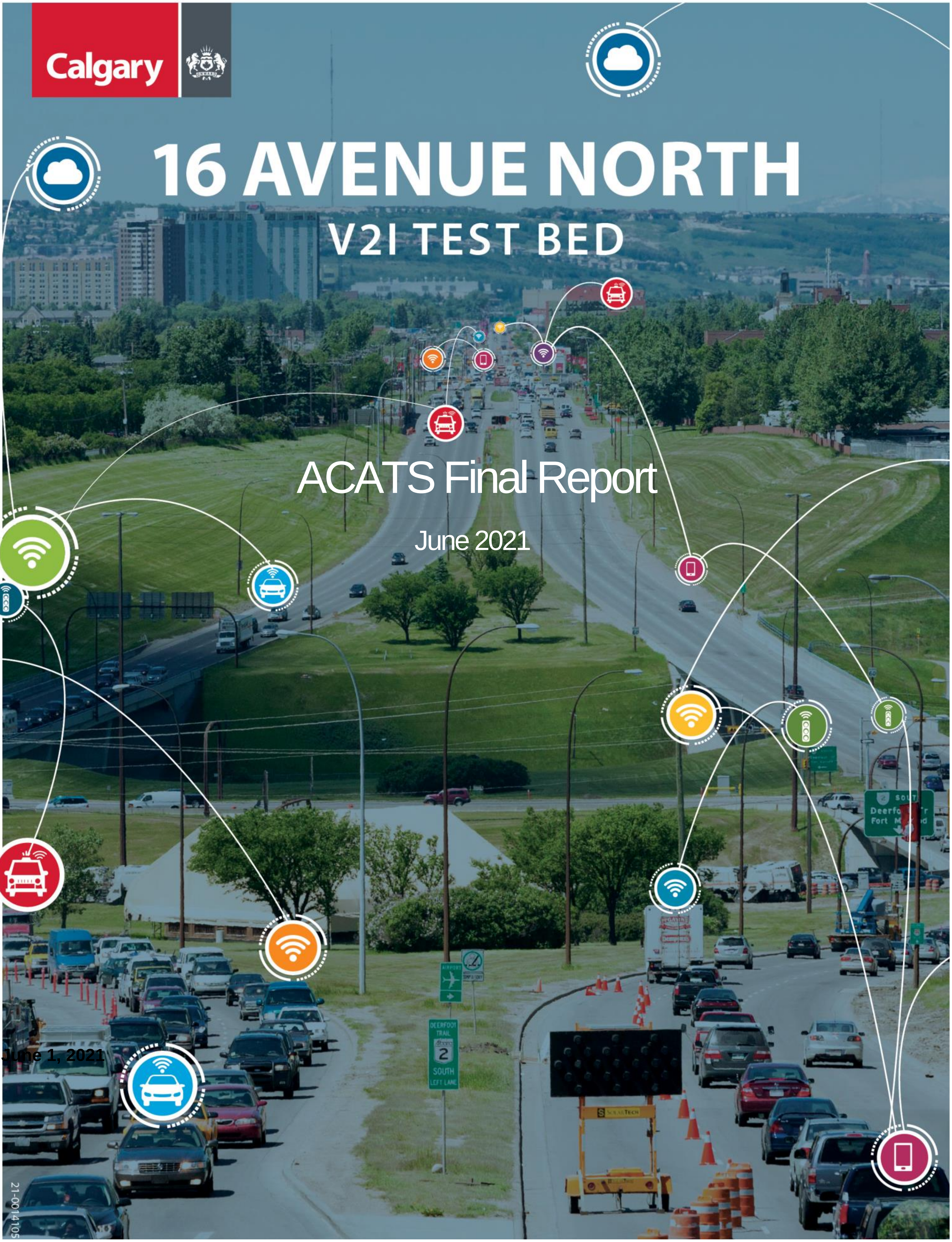
Calgary



16 AVENUE NORTH

V2I TEST BED

ACATS Final Report

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Disclaimer

This project received funding support through Transport Canada's Program to Advance Connectivity and Automation in the Transportation System (ACATS). The opinions expressed are those of the authors and do not necessarily reflect those of Transport Canada.

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List of Acronyms

3rd Generation Partnership Project (3GPP)

Advanced Traffic Controller (ATC)

Advance Connectivity and Automation in the Transportation System (ACATS)

AVL (Automated Vehicle Location)

Calgary Fire Department (CFD)

Canadian National Institute for the Blind (CNIB)

Cellular Vehicle-to-Everything (C-V2X)

Connected and autonomous vehicle (CAV)

Connected vehicle (CV)

Dedicated short-range communication (DSRC)

Emergency Medical Services (EMS)

Federal Communications Commission (FCC)

Gigahertz (GHz)

Global Positioning System (GPS)

Global Traffic Technologies (GTT)

Innovation, Science and Economic Development Canada (ISED)

Intelligent transportation systems (ITS)

Map Data (MAP) – messages that describes the roadway geometry of one or more intersection

Megahertz (MHz)

Multi-Modal Intelligent Traffic Signal System (MMITSS)

National Transportation Communications for ITS Protocol (NTCIP)

On-board equipment (OBE)

On-board unit (OBU)

Proof of Concept (PoC)

Request for Proposals (RFP)

Roadside equipment (RSE)

Roadside unit (RSU)

Security Credential Management Systems (SCMS)

Signal Phase and Time (SPaT) – messages that describe the signal state of the intersection and how long this state will persist for each approach and lane that is active

Signal Request Message (SRM)

Signal Status Message (SSM)

Traffic Management Centre (TMC)

Traveler Information Messages (TIM)

United States Department of Transportation (USDOT)

Vehicle-to-Everything (V2X)

Vehicle-to-Infrastructure (V2I)

Very High Bond (VHB)

Executive Summary

The 16 Avenue North “vehicle-to-infrastructure” (V2I) Test Bed project was created to establish an assessment corridor and initiate trialing of V2I technology. The major goals of the project were to enable transport-sector innovation through the implementation of connected and autonomous vehicle (CAV) technology, and to further understanding through implementation of connected vehicle (CV) applications. The project plan therefore included equipping 12 intersections along 16 Avenue North with dedicated short-range communications (DSRC) roadside equipment, several emergency vehicles with on-board equipment, and trialing a pre-emption application that would utilize this technology. Rather than a pilot project where the equipment would be tested and later removed, this project aimed to enable continued development using V2I technology and will retain the equipment as such. These project goals were met, and plans are ongoing for next steps.

The City of Calgary (The City) set about procuring equipment, software, and technical support through a public Request for Proposals, and selected Kapsch TrafficCom North America (Kapsch) in early 2019. A Proof of Concept was successfully conducted in 2019, leading to the installation and establishment of the 16 Avenue test bed in 2020. Blackberry’s security credential management system (SCMS) was successfully integrated at that time as well.

Opportunities that arose through the course of the project:

- Implementation and testing of “vehicle-to-everything” (V2X) applications, including additional applications beyond those identified in the project proposal.
- Implementation of an SCMS and participation in workshops to aid in the development of surrounding national governance and operational models.
- Installation of roadside equipment and expansion of the originally planned test bed to include additional intersections and off-site laboratory and beta test locations, for a total of 16 roadside installations.

The key takeaways and learnings for V2X projects:

- Applications must be thoroughly tested and ideally involve focus groups to ensure objectives of the applications are met.
- Standalone V2X applications are sometimes less effective than existing alternatives, but when integrated into a system of applications can offer a much more robust alternative.
- Where supporting systems, such as mobile phone technology, are not strong enough yet, there may be a need to implement applications in a phased approach.
- As this technology is far-reaching in terms of potential applications, it will involve engagement and collaboration with many additional stakeholders.
- The use of laboratory environments and temporary installations is invaluable as a first stage, but further testing in a prominent environment provides real-world benefit and public visibility.

Background

The City has a formal intelligent transportation systems (ITS) strategic plan called “Smarter Mobility” which was developed in 2014 and officially approved by Calgary City Council. It provides a vision and direction on implementing ITS elements within the five pillars of mobility: all users, all modes, safe, efficient, sustainable. In 2017, Transport Canada launched the Program to Advance Connectivity and Automation in the Transportation System (ACATS), which provided an opportunity for guidance and funding to explore CAV technology. The idea for the 16 Avenue North Connected Vehicle Test Bed was spawned based on this strategic plan and opportunity. Upon project approval in 2018, The City embarked on establishing this important facility, vital for our progress into the future of CAV.

Connected vehicle technology has many definitions, but its essence is vehicle capability of communicating with vehicle occupants, other vehicles or road users, surrounding transportation infrastructure, or internet-based applications and other entities [1] (Transport Canada, 2021). By this definition, connected vehicle technology has existed and evolved since the invention of vehicles, evolving from fuel gauge to in-ground vehicle detection to infrared-based emergency pre-emption to radio-based DSRC and cellular vehicle-to-everything (C-V2X) communication. However, while gradual in the past, this evolution is accelerating with the advent of V2X communication.

Vehicle-to-vehicle (V2V) and V2I (vehicle-to-infrastructure) were envisioned more than 20 years ago, when the 5.9 gigahertz (GHz) band was allocated to allow for vehicle-to-vehicle radio communications envisioned to advance road safety. While V2I has been poised to take the transportation industry by storm since then, several hurdles meant that it has not been widely deployed yet. Several auto manufacturers had formulating plans to standardize installation of on-board equipment when the debate over communication method erupted: while DSRC had been the prescribed technology for decades, C-V2X had begun gaining traction. This led to a further stall in implementation as both roadway authorities and auto manufacturers waited for a decision. Recent federally-funded American and Canadian programs have helped to spur this momentum, and CV technology has begun rapidly evolving in communication method, scope, and purpose. CV technology is a critical component in optimising safety, efficiency, and information in the transportation network.

Now is the ideal time for cities across Canada to begin implementing CV technology. Equipment is becoming more readily available and robust, supporting systems are simplifying configuration and development, and cybersecurity is being addressed. Furthermore, there is momentum on the decision surrounding communication method. In November 2020, the Federal Communications Commission (FCC) officially re-allocated the 75 megahertz (MHz) band previously allocated to DSRC for transportation applications within the United States. The lower 45 MHz has been allocated to unlicensed used, and the upper 30 MHz (5.895-8.925) to ITS systems that must use C-V2X technology. Both because Innovation, Science and Economic Development Canada (ISED) is expected to follow suit, and because interoperability of equipment is a priority within North America, The City of Calgary anticipates migration to C-V2X.

Goal #1 - Establish Test Bed

The City of Calgary aimed to enable transport-sector innovation, capacity-building, research, and development on CAV and transportation-related issues. In the short term, this is achieved by providing a test-bed to support internal and third-party research and development; and in the long term by preparing The City for the arrival of automated vehicles. The chosen location for this test bed is 16th Avenue North, an important link of the historic Trans-Canada Highway. Implementing in such a prominent location has the benefit of appealing to the public at large and providing significant and tangible benefits. 16 Avenue is a key link in Calgary's transportation network, with 3 fire stations, an emergency medical services (EMS) station, a hospital, and two major post-secondary institutions in proximity. It is frequently used as a part of emergency vehicle routing. Some intersections along the corridor were already equipped for emergency pre-emption, which allowed for data comparison in order to determine if equipment was functioning. However, it was not available at all locations: this too is beneficial because we are able to reduce travel time by providing pre-emption at those intersections.

Figure 1: Overview of 16 Avenue Test-Bed

Establishment of a test bed entailed:

- Proof of Concept to ensure the appropriateness of the award of the full contract.
- Preparation of corridor to identify ideal mounting locations, prepare and upgrade infrastructure as required to support roadside devices physically and operationally.
- Installation and configuration of roadside equipment.
- System configuration and management to ensure devices are configured and reporting appropriately.
- Integration of an SCMS to allow testing of applications in a secure environment.

Proof of Concept

A Proof of Concept (PoC) was included in the Request for Proposal to ensure the equipment and application functionality, product delivery, and support were satisfactory before award. In August of 2019, the Proof of Concept was implemented over the course of one week, with two sites equipped with RSUs and test vehicles equipped with OBUs. One test site was established in a closed laboratory environment within the City of Calgary Spring Gardens compound. This is a traffic signal used for technician training and is complete with a control cabinet and signal displays. It was therefore an excellent choice for initial testing. The other test site is located nearby at 32 Avenue & 6 Street NE, a location that did not previously have emergency pre-emption activated, operates in an uncoordinated mode, has low traffic and pedestrian volumes, and can be easily accessed by field crews if problems arise. This allows testing of technology and applications in a phased approach: first in the lab environment, then in our beta test location.

Figure 2: Proof of Concept Sites

Corridor Preparation

One of the reasons this corridor was selected was its readiness. While most of the traffic controllers had not been upgraded to the required standard, the corridor was ideal in terms of roadway curvature, geometry, grade, and readiness of existing infrastructure. Much of the physical infrastructure (signal steel and underground conduit) had been upgraded recently, which minimised expensive and time-consuming upgrade requirements. Communications to the Traffic Management Centre (TMC) had already been established and was planned for upgrade to fibre optic connection. The corridor follows a straight east-west line along this section, with few physical obstructions. Traffic signals are spaced along the corridor at relatively regular intervals, with most spaced approximately 300 to 400 metres apart. This is ideal for the use of the DSRC, with a typical range of 300m but often significantly longer.

The corridor was analysed in August 2019 to identify ideal mounting of roadside units. Roadside units were mounted on traffic signals poles nearby to the signals cabinets in order to minimise ethernet cable runs back to these cabinets, while ensuring appropriate mounting height. Additionally, physical obstructions were avoided: while line of sight is not required, obstructions such as buildings and tree canopies can impact signal strength.

A critical preparation was ensuring compatibility of the traffic signal controller with the equipment. In order to support the necessary connected vehicle interface, modern traffic controllers are necessary. Specifically, traffic controllers must comply with The National Transportation Communications for ITS Protocol (NTCIP) 1202 standard, version 3, which defines objects for actuated signal controllers interface and includes support for CV interface. However, most of the signalised intersections along the 16 Avenue North corridor were operating using legacy traffic signal controllers which would not have been compatible. Replacement of the signal controllers was therefore critical.

Figure 3: *Intelight and Econolite Traffic Controllers (Sources: Q-Free America, Econolite Canada Inc.)*

At the time of contract award, drafts for NTCIP1202 V03 had been circulated, but this version of the standard wasn't published until February 2019. Fortunately, The City currently uses two controllers that support this standard: the Intelight X3 and Econolite Cobalt advanced traffic controllers (ATC). Before the project began, our vendors confirmed that these controllers were CV-ready. As the City already had experience with the Intelight controller and Econolite was new to Calgary, only the Intelight controllers were installed along this corridor. The Intelight X3 compatibility was proven through the PoC before installation along the corridor. Later, the Econolite Cobalt controller was tested and verified at the lab test location.

Communications was critical to establish a connection to the Traffic Management Centre (for monitoring purposes) to the Kapsch server, and to the SCMS server. Network restrictions meant to secure the City of Calgary network also meant that it was necessary to use separate modems for the RSUs to communicate with the cloud.

The City of Calgary installs and maintains traffic signals equipment through the Signals Maintenance and Construction division. Employing internal resources for this work meant that staff could be allocated to this project to replace the traffic signal controllers and establish required communications in advance of the roadside equipment installations. Likewise, City resources were dedicated to installation and troubleshooting of the roadside units.

Equipment Installation

The City of Calgary had initially released a Request for Proposal that specified DSRC equipment. At the time of the RFP posting, it was unclear whether industry would continue to pursue DSRC or adopt C-V2X as its standard. Additionally, DSRC equipment was much more widely available at the time. Kapsch proposed two alternatives for roadside units: V2X roadside ITS Station RIS-9160 or RIS-9260. The RIS-9260 has the added capability of C-V2X communication module using 3rd Generation Partnership Project (3GPP) Release 14. In order to futureproof our corridor, The City of Calgary chose this roadside unit. To date, it has been tested only in DSRC mode. However, it's anticipated that C-V2X mode will soon be tested as well.

Over the course of a week in January 2020, the corridor was configured and tested using an OBU in a test vehicle. The Kapsch Insight and V2X Assist applications were used to validate SPaT and MAP data broadcast. Each intersection was proven to reliably report signal phase status and approach lane configuration.

Once again, the preemption application was also tested and responded as anticipated. At this time, we were able to test the preemption application using a temporary installation in a fire truck, which also operated as intended, activating only when the parking brake was de-activated and beacons were activated. Shortly after, the SCMS was successfully migrated to the production environment and a permanent installation for a fire truck was implemented. This permanent installation was tested in early March of 2020, shortly before COVID-19 lockdown went into effect, and operated as intended.

Figure 4: *RSU Installed at 16 Avenue & 14 Street NW*

System Configuration and Management

Kapsch offered their Connected Mobility Control Center (CMCC) as a part of their proposal. It is currently cloud-based but may be considered for on-site server hosting in the future. Kapsch defines CMCC as “an operational solution that manages and monitors connected mobility devices and device messaging”. CMCC functionality includes:

• **Asset Management:** Each location and its associated equipment can be defined and information on it maintained. Most configurations are set at the location level, rather than the device level.

• **MAP Generation:** Build MAP messages via an intuitive graphical user interface format directly on a Google map view of the intersection or road segment. Each approach and lane is defined for allowed movements and associated signal phases, including pedestrian movements. If additional accuracy is required, data point corrections can be added manually.

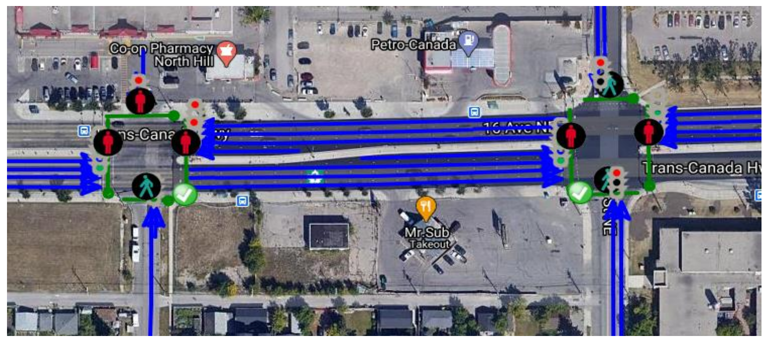


Figure 5: MAP file imagery

• **TIM Message Generation:** Build and distributing Traveler Information Messages (TIM)

• **Message Definition and Scheduling:** RSU messages can be created and configured via robust scheduling. This includes the ability to set specific times, days of the week, and intervals in which messages will be transmitted.

• **Data Management:** Real-time traffic information can be monitored at any location. This includes traffic signal phasing and all communication between RSUs, OBUs, and pedestrians.

• **Automated Monitoring and Alert:** Dashboards and statuses provide the ability to monitor all devices within the network to detect any issues in connectivity or messaging. Users can register for alerts to be notified when issues arise with equipment, system functions, or recorded data.

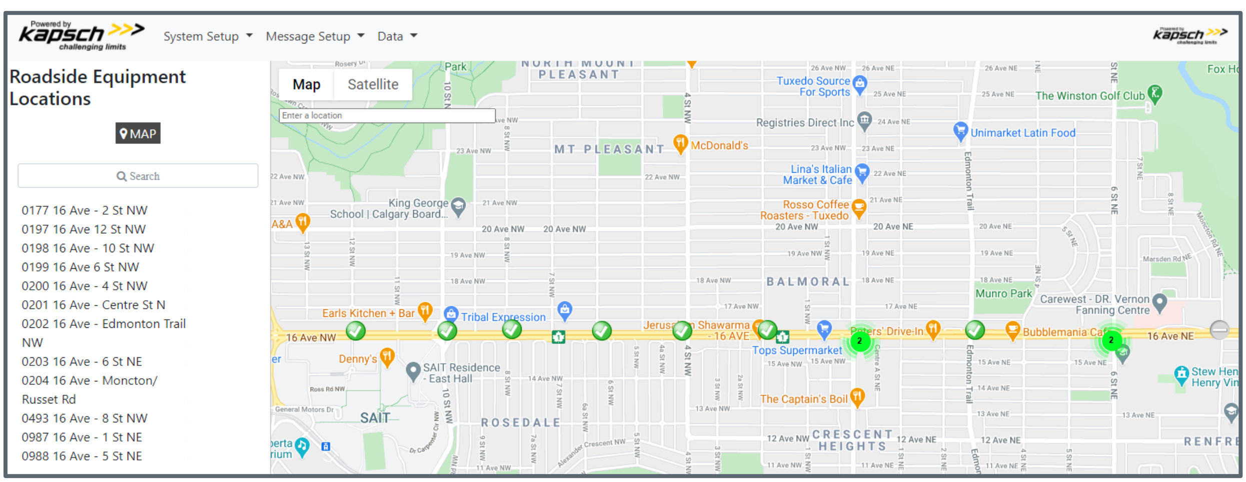


Figure 6: CMCC Roadside Equipment Overview

Security Credential Management System

Implementation of an SCMS was not planned for the proof of concept, as it was desired to first establish the equipment and application in the test environment. However, once the PoC was completed, planning began for the next stage of project implementation. The SCMS protects both The City and the Public by using digital signatures endorsed by specialized digital certificates or security credentials. This is necessary for connected vehicles in order to ensure messages can be trusted. The SCMS must ensure the message has integrity, authenticity, and that any private information is not disclosed. If a message were falsified or tampered with, it could have serious safety repercussions in the field.

During the course of the project, Transport Canada was pursuing development of a Canadian standardized SCMS. Transport Canada awarded a contract to ESCRYPT to pursue this in March of 2019. Since then, ESCRYPT has been working with stakeholders in Canada to develop requirements for the system and recommend an operational model for how the system can be utilised in Canada.

Fortunately, in December 2018 Blackberry Certicom began offering a free trial SCMS service, and The City decided to implement this system on this trial basis. The team wanted to implement the SCMS and configuration of 16 Avenue Test Bed together to ensure security of our major corridor. As such, coordination of this as well as time required to procure materials meant that installation and configuration on 16 Avenue was completed in January 2020, somewhat later than originally anticipated.

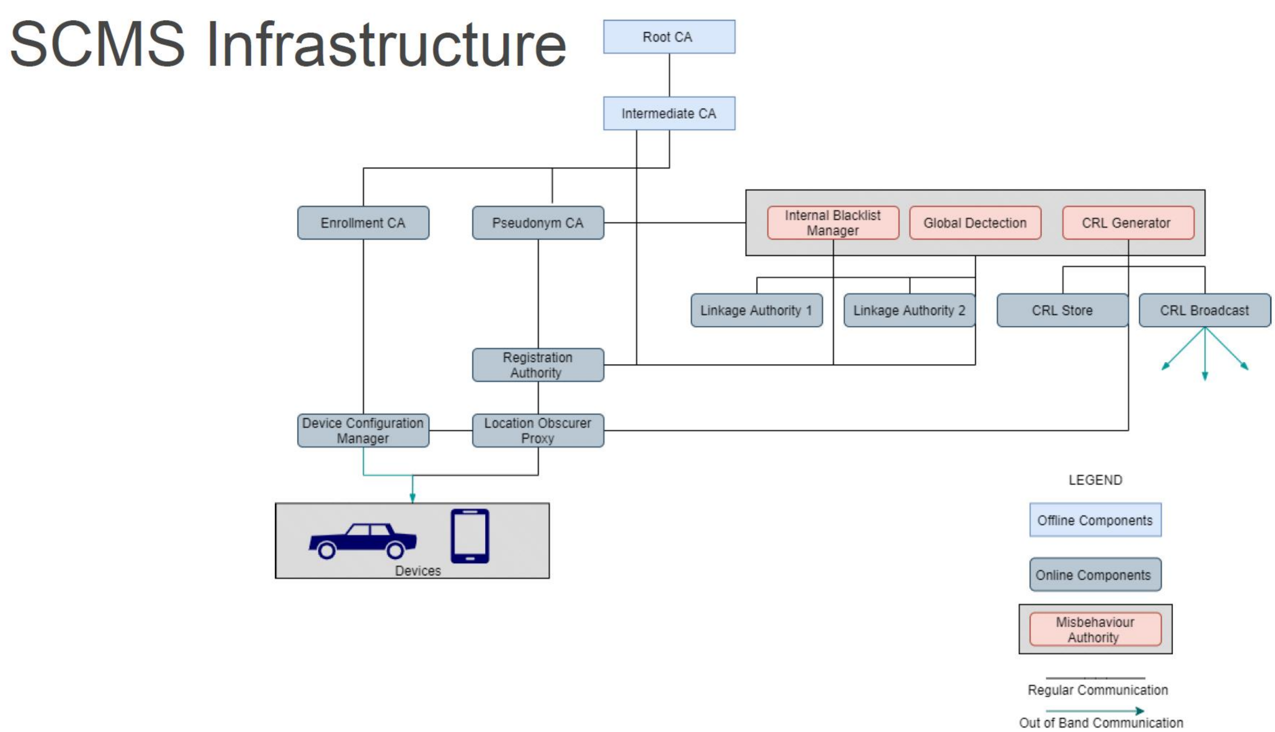


Figure 7: *SCMS Infrastructure (Source: Blackberry)*

Blackberry production release of their SCMS has been operational since early 2019, released at that time without the full architecture that is intended for eventual deployment. The current implementation of the SCMS used for this project was achieved by pre-loading several months worth of certificates onto OBUs, with RSUs downloading certificates on a weekly basis.

The SCMS platform was integrated with Calgary’s equipment using a cloud-hosted server, however this may be reconsidered for local hosting of a server in the future to allow better control by The City’s own resources. As a stakeholder, Blackberry Certicom has maintained involvement with TAC’s development of SCMS operating and governance models.

Goal #2 – Test and Implement CV Applications

In order to provide an immediate and tangible benefit to both the the Corporation as well as to the Public, applications were identified that could be implemented through use of City vehicles.

Four applications provided by Kapsch were ultimately tested:

- V2X Insight: CV validator
- V2X Assist: builds on basic SPaT and MAP data
- Signal pre-emption/ priority
- eWalk: aimed at visually impaired pedestrians

The primary focus of application testing was the emergency pre-emption application. It was identified as an ideal opportunity because it provides the benefits of both reduced travel time and protected progression for emergency vehicles. Furthermore, testing of this application allows comparison against established technology. This allowed The City to compare reliability as well as usefulness in terms of the duration before arrival that the call is received. As several gaps in availability of emergency pre-emption existed along the corridor, this also allowed The City to add this benefit where it did not already exist.

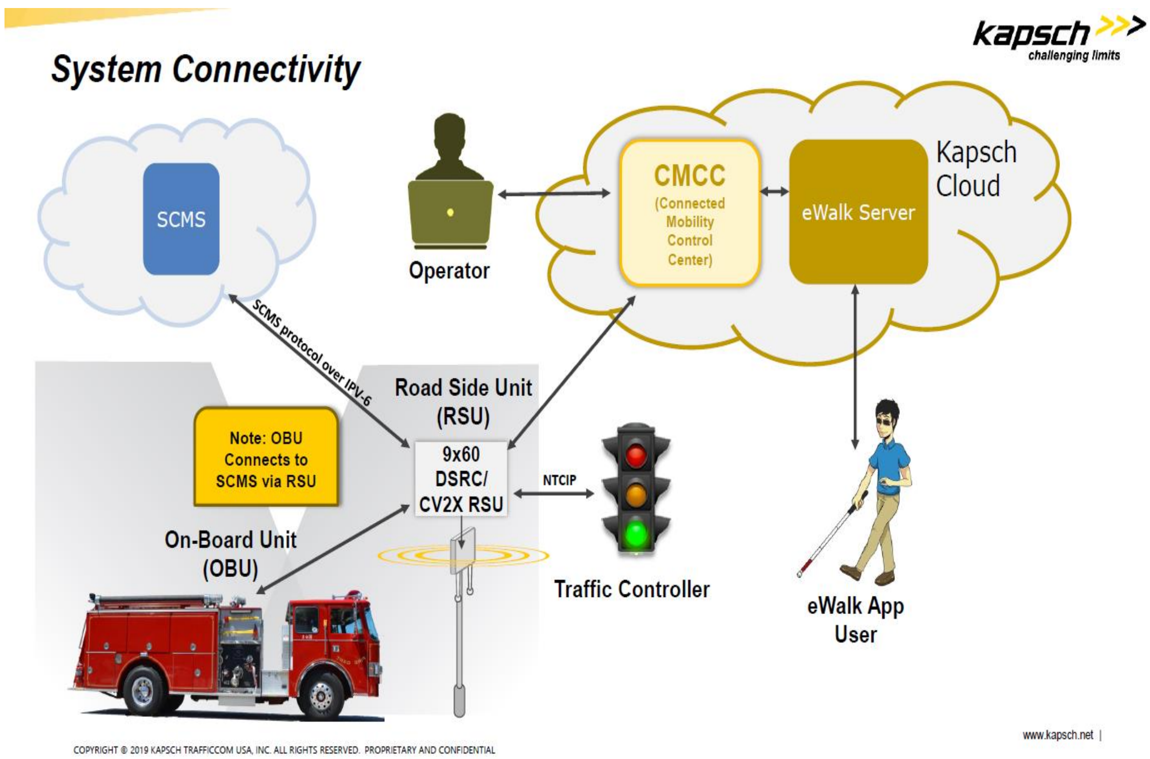


Figure 8: *Kapsch System Connectivity (Source: Kapsch)*

Kapsch V2X Insight

The V2X Insight application is essentially a CV validator, and was utilized in order to ensure accuracy of RSU configuration in terms of both SPaT and MAP messaging. It enables connection to roadside units in the field for monitoring purposes. It provides audio and visual alerts and includes:

- Map display showing the position of connected on-board units, current state of traffic signals, and visualisation of MAP files.
- Message display: shows message processing as they are transmitted and received.
- Logs: provides real-time log data.
- Settings: allows certain controls on the units and for the application itself.

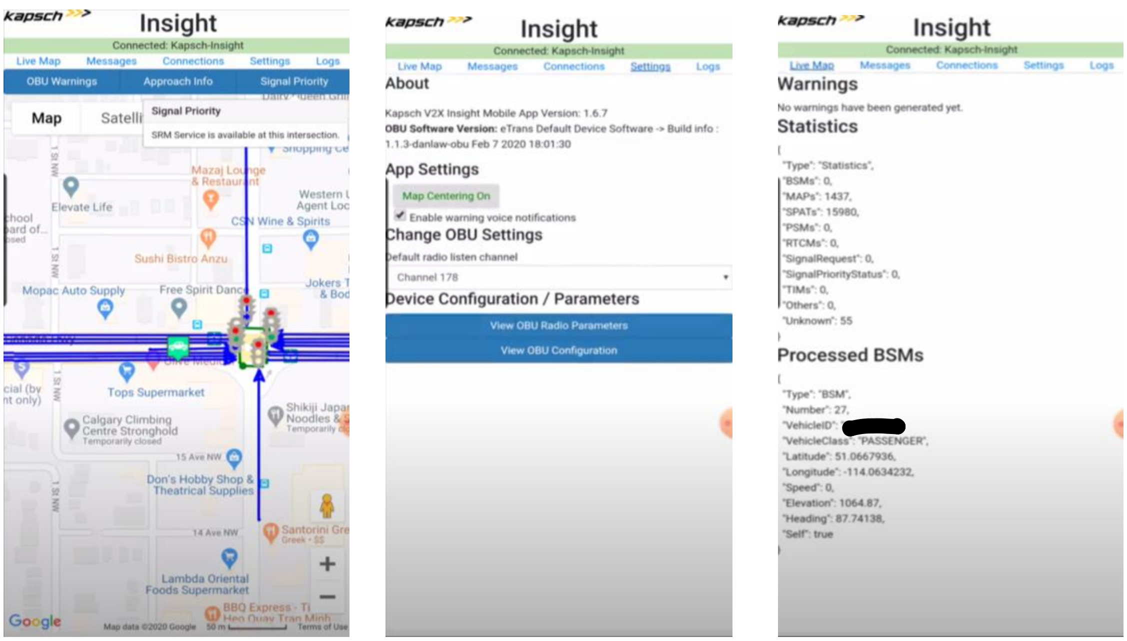


Figure 9: Kapsch V2X Insight Overview

Kapsch V2X Assist

The V2X Assist application combines the functionality of several CV application concepts. This application was not the focus of the project, and was utilized and verified but not fully tested. Functionality includes:

- SPaT: The base screen (if not on an approach for a traffic signal/ no active warnings) shows the speed of the vehicle and the number of vehicles and intersections that are being tracked over DSRC. If the vehicle is on an approach for an equipped signal, Assist will show the phase and timing of the light. It displays a countdown to the end of green or to start of green, as appropriate. The traffic signal must be programmed in coordinated mode to have full functionality of countdown information.
- Red light violation warning: The application combines information from the MAP and SPaT data files with predicted vehicle arrival to determine whether the signal ahead will be red upon arrival at the intersection. It provides a visual and audible red light warning if predicted to arrive on red.
- Pedestrian or vehicle collision warning: If other V2X enabled vehicles or pedestrians are approaching or in the intersection, provides a collision warning if applicable. The application combines information from multiple equipped vehicles and pedestrians to warn drivers of vehicles braking ahead, potential collision with a vehicle on another approach, or pedestrian presence in a crosswalk the driver is approaching.
- Speed warning assist: The application recognizes speed limits, including broadcast temporary speed limits for construction. It can warn drivers as they approach the speed reduction zone, or if they are exceeding the speed limit.

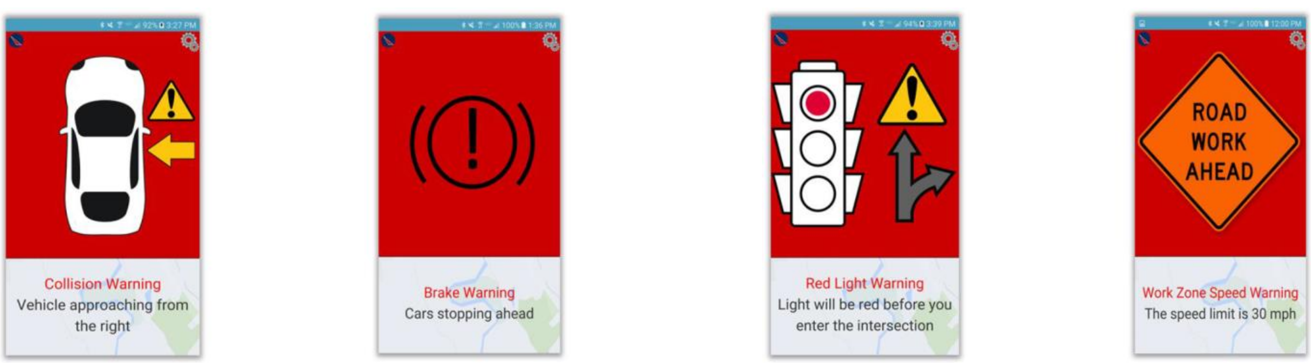
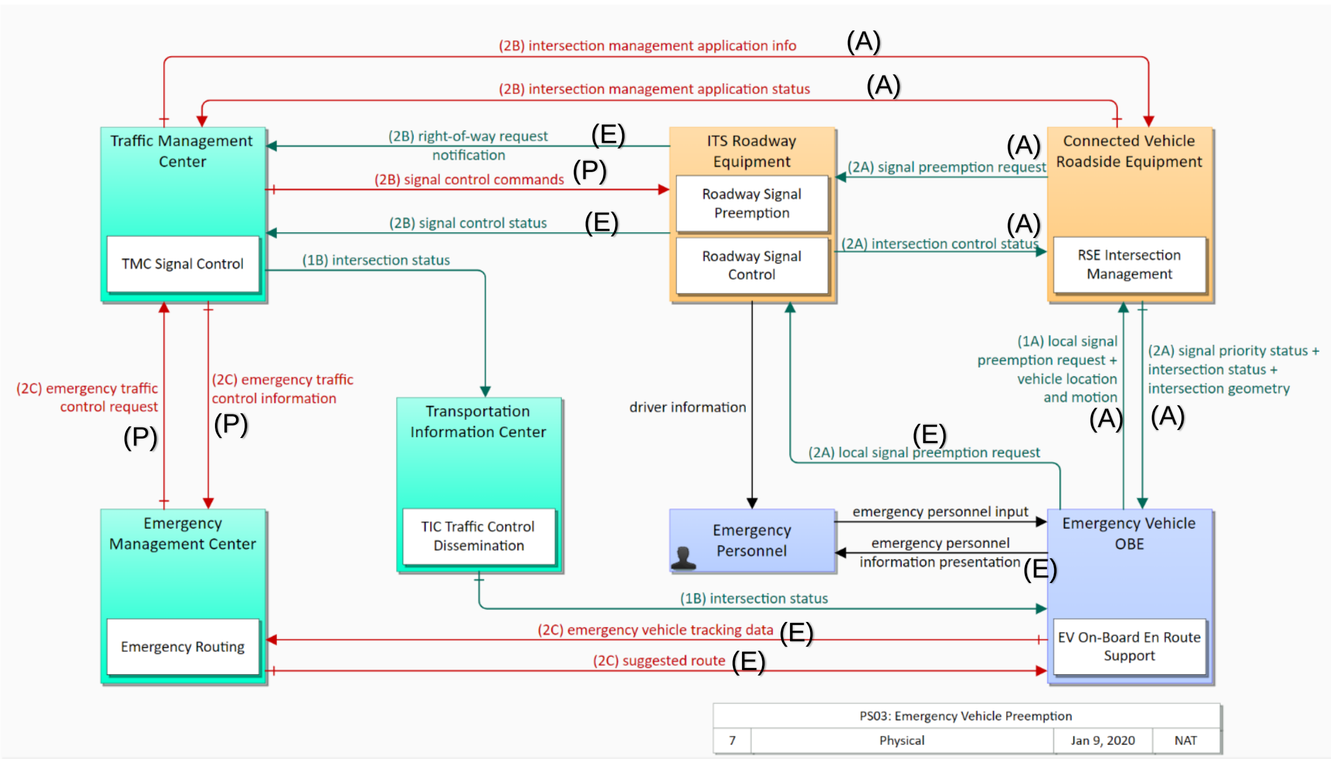


Figure 10: *Kapsch V2X Assist Sample Warnings (Source: Kapsch TrafficCom)*

Emergency Vehicle Preemption

Design

The emergency vehicle pre-emption application was identified as a desirable application for V2I testing. This was also a factor in the choice of 16 Avenue as the test bed location: this corridor is frequently used as a part of emergency vehicle routing. Some intersections along the corridor were already equipped for emergency pre-emption. The presence of alternative methods allows us to compare system logs to determine if both methods are functioning, while the absence at some intersections allows us to gain a benefit from addition of pre-emption.



(E) = Pre-existing
(A) = Added through this project
(P) = Planned

Figure 11: *ITS Architecture service package on Emergency Vehicle Preemption [2] (USDOT, 2021)*

Figure 11 indicates ITS architecture service package as defined by the United States Department of Transportation (USDOT), and has been marked to indicate those methods pre-existing in Calgary, those added through this project, and those planned for future integration.

Alternative methods of emergency pre-emption may be achieved as indicated:

1. request via on-board equipment to roadside equipment (CV or other equipment)
2. request via emergency management centre to traffic management centre to roadside equipment

The City of Calgary currently uses several methods for emergency pre-emption:

- hardwired connection from fire stations to nearby traffic signals. This is often used in order to prepare the first signal or pair of signals an emergency vehicle will encounter upon leaving the station.
- Global Traffic Technologies (GTT) Opticom infrared solution uses on-board equipment that generates an infrared pulse; the roadside detector activates a physical input to the traffic signal controller. This equipment has been used in Calgary for many years but is no longer the standard treatment because it requires line of sight to operate.
- GTT's radio-enabled solution uses 2.4 GHz radio-based communication and global positioning system (GPS) location to activate pre-emption. This method is similar to the infrared solution because it also generates a physical input to the controller, but does not require line of sight, can reach a long range, and can integrate the vehicle's turn signal information to pre-empt the appropriate downstream intersections. This method is used at many intersections along 16 Avenue. While similar to V2I communication in that this uses a radio signal, it does not enable two-way communication, nor does the roadside equipment use NTCIP messaging to communicate directly with the traffic signal controller.

The V2I preemption application implemented is similar to the above Opticom methods in terms of operation: the on-board equipment communicates a request for pre-emption to roadside equipment, which translates this message to the traffic controller. V2I preemption was added at several intersections and/or several previously unequipped directions. While addition of pre-emption provided a benefit to the Calgary Fire Department (CFD), the use of this application through the MAP-enabled V2I may actually be less effective in reducing travel time in comparison to the existing alternative methods currently used along 16 Avenue. This is for 2 reasons: 1) the pre-emption input only begins as far back as MAP file for the intersection (i.e. only after the upstream intersection is passed), and 2) range of DSRC may be shorter compared to alternative methods used.

The most important and advantageous differences between the V2I method and these other methods already in use are:

- Messages are exchanged between the OBE and RSE, rather than only received by the RSE. This allows the signal controller to provide information back to the emergency vehicle. This information may include: signal status message (SSM), SPaT information, or TIM based on detected equipped road users in the area. Warnings may include pedestrian in crosswalk or predicted collision warnings, for instance.

- Information received by the RSU can also be communicated to other road users, potentially warning drivers or pedestrians of approaching emergency vehicles, for example.

- The application can be integrated into a more complex system. Ultimately, this will be integrated into a broader system to manage multi-modal demands, including emergency vehicles, transit, freight, pedestrians, cyclists, and motorists. The vision for the multi-modal intelligent traffic signal system (MMITSS) application is to “provide overarching system optimization that accommodates transit and freight signal priority, preemption for emergency vehicles, and pedestrian movements while maximizing overall arterial network performance.” [3] (USDOT, 2021) It incorporates multiple interconnected applications to safely and effectively balance intersection demands.

At this time, the Calgary Fire Department opted not to integrate the OBE with a human-machine interface that would provide feedback from the signal controller. This decision was largely made because CFD staff already have an overwhelming amount of information they are responding to en route. Given the current lack of equipped road users, the information that the traffic signal could provide was not considered sufficiently valuable, and rather was considered an unnecessary distraction. As the system grows and evolves this may change.

The preemption application used in this study employed simple criteria to activate the SRM (signal request message):

- Vehicle approaching an enabled intersection in a direction of travel with an enabled pre-emption routine

- Vehicle emergency lights activated and parking brake de-activated (this was already pre-wired in the vehicles as a condition of the existing pre-emption technology)

As we employed an SCMS, the signal request message would be rejected if the on-board units were not configured and certified to enable pre-emption. It was verified that the preemption application did not function if SCMS certificates were not installed on the OBU.

Implementation

The City of Calgary posted an RFP in December 2018, which included supply of roadside and on-board equipment, supporting software, technical support and, specifically, provision of an emergency pre-emption application. Fortunately, the successful bidder (Kapsch) had already developed such an application. However, equipment installation was not planned until after the PoC had demonstrated functionality.

The Calgary Fire Department was amenable to installing equipment in their vehicles, but wanted to be sure it was as inobtrusive as possible. They required equipment that would take minimal space to install, had minimal power demand, and could be wired to the vehicle easily to operate the pre-emption only when conditions were met. They also wanted to avoid the need to drill holes for antenna installation. The City therefore selected the Danlaw Through Glass Integrated V2X antennas for installation, which uses a coupler to pair the external antenna with the internal cables.

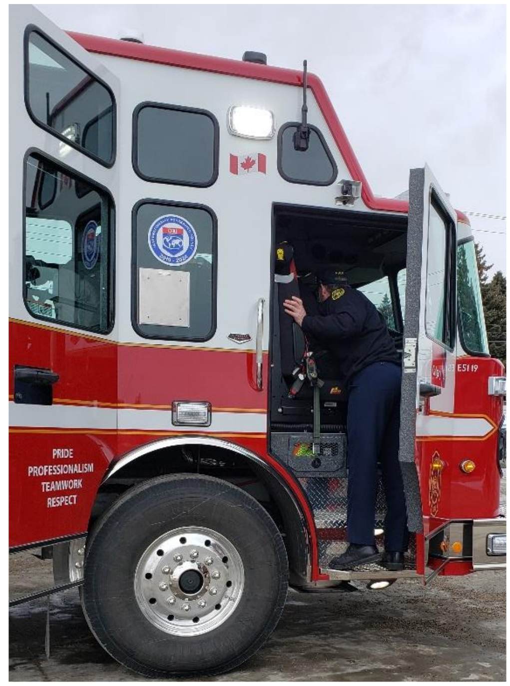


Figure 12: *V2X Equipped Fire Truck Showing Through Glass Antenna*

Coordination of installation and testing of equipment in CFD emergency vehicles proved challenging. These vehicles had to be taken out of service in order to complete the work. All equipment was required to be on hand and pre-configured. In January 2020 the 16 Avenue corridor was established, SCMS configured, and pre-emption application tested using a CFD temporary installation that demonstrated the incorporation of the SCMS and conditional activation. Once materials were available for the permanent installation, CFD was able to coordinate installation for March 2020 in one of the vehicles, however challenges delayed permanent installation until January 2021 when all 4 vehicles were completed.

Several challenges were faced with installation and testing of on-board equipment:

- Initially it was desired to have the option to remove the V2X antenna and re-use on another vehicle. The primary reason for this is that emergency vehicles may be re-deployed to other stations based on need and life cycling. The recommended installation, however, specifies a high-strength industrial adhesive that must be pried off, which normally destroys the antenna. To promote re-use, The City decided to trial the use of VHB (very high bond) tape instead. Danlaw cautioned that this may prove insufficient, and that it may be necessary to replace this tape frequently. Therefore, this was initially tested on one unit only. The tape failed within two months of installation. At that time, it was determined instead to use the recommended adhesive – which was not readily available. This led to further delay in procuring the adhesive and applicator. However, since the approved adhesive has been in use, all antennas have remained in place.

- Installation is performed by contract labour rather than by CFD staff. Scheduling of this work becomes complex as it must be coordinated between CFD and this contractor, and requires the emergency vehicle to be temporarily removed from service. Removing a vehicle from service requires accommodation to ensure sufficient vehicles are available for response at all times.

- Only one permanent installation had been completed before COVID lockdowns went into effect in late March 2020. This severely hampered efforts, as non-essential activities were eliminated for a long period of time and personnel restricted at fire stations.

- Contract staff who perform installation are not certified to perform testing outside of CFD property. Likewise, staff certified to drive these vehicles on the roadway are not readily available to be removed from other duties to conduct testing. Test equipment outside of the City of Calgary lab environment was not considered as a part of this project; therefore, installation verification was difficult to coordinate. After installation, units were put into service to assess operation. Unfortunately, one unit was not wired correctly; scheduling of remedial work caused delay.

Data Collection and Analysis

Data was collected over the course of several months to determine the benefit of implementing the pre-emption application. Data collection was tedious because it required comparison of data to determine when equipped vehicles were travelling along the corridor, if they should have been activating a V2I pre-emption at the time (based on whether another method was active), and what the travel time was from each intersection to the next for each vehicle.

Because only 4 vehicles were equipped, and testing was limited to situations where the equipped vehicles would use 16 Avenue as part of their travel route, opportunity for data collection was somewhat limited. In order to conduct a valid comparison, only pre-emption events during like travel pattern peak periods were compared. Only AM peak and PM peak comparisons were conducted, as too few events occurred within other similar timeframes to conduct a valid comparison. Likewise, too few and short eastbound pre-emption events occurred to conduct a valid comparison.

In order to measure impact on travel time, we considered four data sources:

1. Calgary Fire Department's automated vehicle location (AVL) system: this would capture and allow extraction of data for only those equipped vehicles. This would form the basis of anticipated V2I preemptions.

2. The TMC's central traffic signal system data collection captures logs of both activated preemptions and SRMs. This would form the basis of verified pre-emption calls received and preemptions activated.

3. Traffic signal controller logs can be extracted to verify validity of the TMC-collected data or be used in lieu of this data. However, this data is

4. CMCC can be used to collect data. However, it has not been configured yet to retrieve the SRM and SSM data. Furthermore, if it was used, this would verify that the request was sent and acknowledged, but not that the pre-emption routine was executed.

It was therefore decided that rather than pursue data collection using the CMCC system, data would be collected using CFD AVL system (#1) and compared to data from central control system (#2). Only in the case where unexpected data resulted would additional sources be consulted.

Figure 13: *Data Collection and Analysis Procedure*

Travel time was calculated separately for each trip made by equipped vehicles between equipped intersections. Calgary Fire Department collects data using their AVL system. This data provides heading and speed of vehicles and is trackable to each specific vehicle. We could therefore isolate trips by V2I equipped vehicles. However, the AVL data is collected at specific intervals rather than specific locations, so while the location of a data point could be isolated, it could not be pinpointed precisely to the centre of an intersection. Instead, each data point was correlated with nearby intersections, average speed from the previous point calculated based on distance and time, and this speed was used to calculate travel time from centre to centre between intersections.

There are many reasons why travel times may be significantly longer than usual, such as unusual congestion caused by detours or incidents either on this or alternative travel routes, malfunction of a traffic control device, vehicle intentionally stopping but continuing to pre-empt, etc. Because this outlier data can have a large impact on averages, and because it is difficult to determine the underlying causes of it, the outlier data was removed from the data set (for both before and after data). To avoid removing too much data, only those values that fell outside of three times the standard deviation were removed. The standard deviation was iteratively adjusted upon outlier removal until all included values fell within the appropriate range.

Data was anticipated to be difficult to interpret due to impacts by road conditions and the irregular impact of COVID-19 on traffic patterns. To account for this, percentage change in travel time was compared for intersections with previously existing pre-emption versus those with newly-added pre-emption. This allowed us to eliminate the impact of these factors from our data, and we inferred that:

If travel time decreases significantly for those intersections with newly-activated V2I pre-emption, but not for those with pre-existing pre-emption, then the reason for this decrease is expected to be directly related to the impact of V2X pre-emption.

Results

Data was collected over a period of approximately 6 months to analyse the “before” condition, and 3 months to analyse the “after” condition. Sufficient data was gathered to make a valid comparison for the AM and PM peak periods for the eastbound direction. However, too few trips were made in the westbound direction to allow making a comparison for any particular time of day. The result for the eastbound direction was that a significant decrease in travel time was observed after CV pre-emption was activated, particularly for the PM peak. The result of data collection illustrated that pre-emption was performing as desired Cumulative travel time is shown for before and after data below in Figures 14 and 15.

The result was that a decrease was observed for the eastbound direction, particularly in the AM peak. Before vs after data showed a 13% overall reduction in travel time for the AM peak, 6% for the PM peak, and 3% off peak.

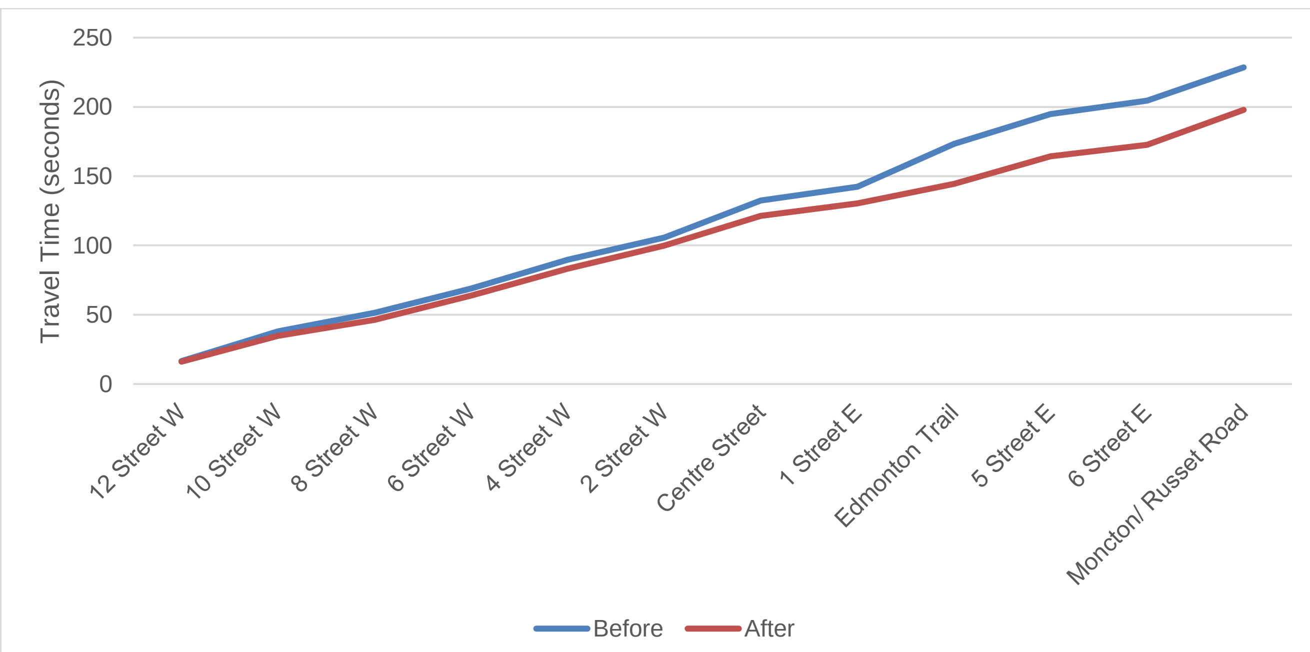


Figure 14: AM Peak Cumulative Travel Time

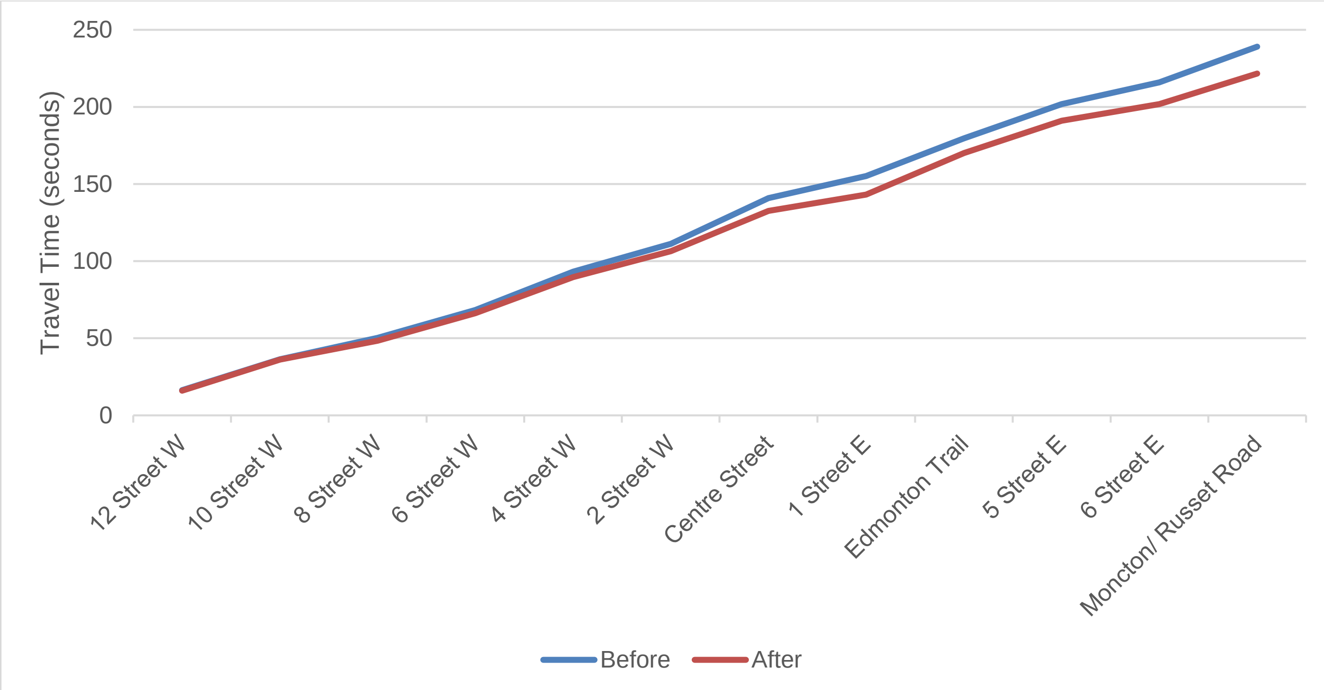


Figure 15: PM Peak Cumulative Travel Time

The impact of COVID-19 on traffic has been relatively uneven and sporadic. There was risk that conducting the before and after comparison would be impacted by COVID traffic fluctuations and would not represent a true comparison. Therefore, travel time changes were specifically noted for intersections where pre-emption was added versus where pre-emption was existing. It was anticipated that there would be a more significant improvement for those locations where pre-emption was added, but that those where pre-emption was existing would also see some improvement. The reason improvement at already-equipped intersections was expected was that emergency vehicles are anticipated to bypass the previous signal at a higher speed, therefore would avoid accelerating from that intersection. This was, however, expected to represent a small time savings in comparison with those intersections where pre-emption was added. This was, indeed, the case, as represented in Figure 16. In the AM peak, travel time greatly reduced where pre-emption was added (16.2%), and slightly (4.5%) reduced where it had already existed. For the PM peak, although the time savings were smaller than desired overall, this same trend was observed. A 7.3% savings was realized where pre-emption was added and only 2.1% where pre-emption was pre-existing. These results support the validity of the conclusion drawn from the data: that the reduction in travel time is directly related to the addition of CV pre-emption.

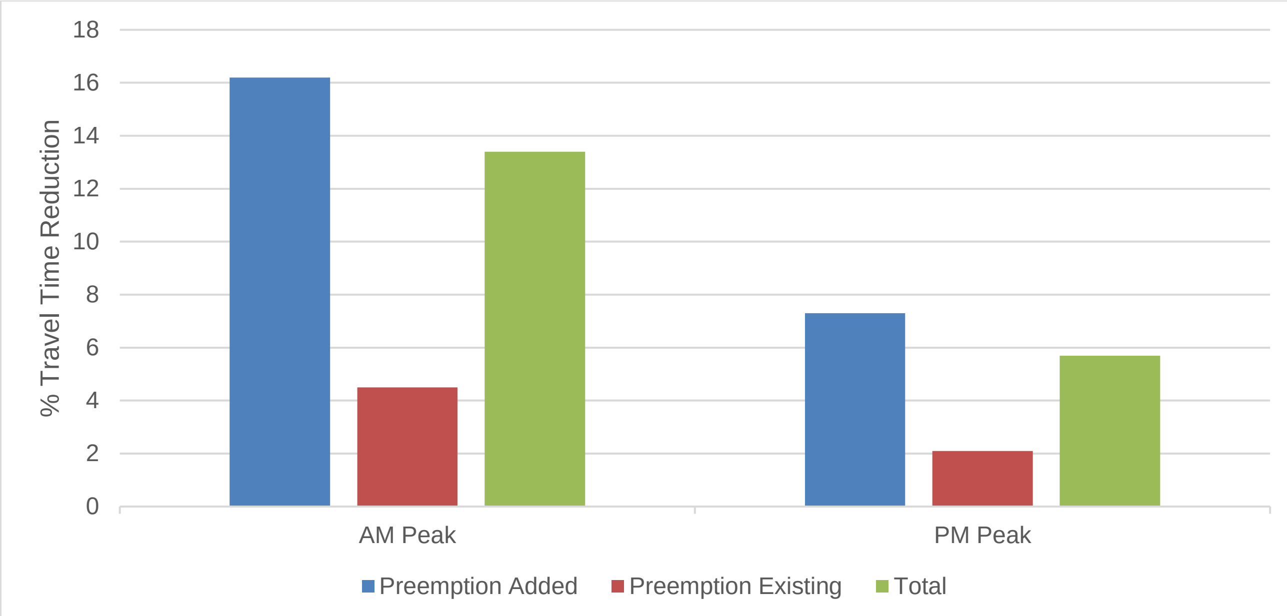


Figure 16: *Travel Time Reduction – Preemption Added vs Existing*

Kapsch eWalk

Design

Mobile accessible pedestrian signal (MAPS) applications are intended to enable the pedestrian to actuate the pedestrian phase of a traffic signal from their smart phone, and provide visual and audio cues to help safely navigate the crosswalk. Kapsch developed an application, dubbed eWalk, that serves this purpose and integrates additional functionality. This application was made available at an additional cost to the original contract. As this was not a part of the original project scope, this was not eligible for ACATS funding. However, as the potential benefit was high and the incremental cost to implement was low, The City of Calgary opted to test this application as well.

Figure 17: *eWalk Visual Display of Pedestrian Clearance Countdown*

The accessible pedestrian application was implemented at the test intersections. The application is available for download on Android and iPhone smart phones. It allows users to use speech recognition and verbose (descriptive) mode, amongst other settings. Because pedestrians do not typically have DSRC radios, it instead relies on IP-based communication to a cloud server to host the two-way communication required between a user's smart phone and an RSU. Direct DSRC communications are typically achieved at 15ms latency, while this application relies on cellular phone and RSU cloud-based data exchange, which can be much slower. Some noticeable delay may therefore be linked to this. Nonetheless, this provides a reasonable method to achieve pedestrian connectivity without requiring additional equipment.

This application provides audio and visual cues to a pedestrian to:

- Inform when they are approaching an eWalk-enabled intersection.
- Inform when they are near the crosswalk but not yet facing it.
- Inform when they are facing a crosswalk, and which crosswalk they are facing.
- Inform how to and allow a pedestrian to request the Walk phase for this crosswalk.
- Inform if the crosswalk is in a Walk phase or if a pedestrian must wait.
- Count down the pedestrian clearance time, regardless of whether this is provided on the pedestrian display.
- Warn if they wander outside of the crosswalk.
- Inform when they have reached the opposite curb.

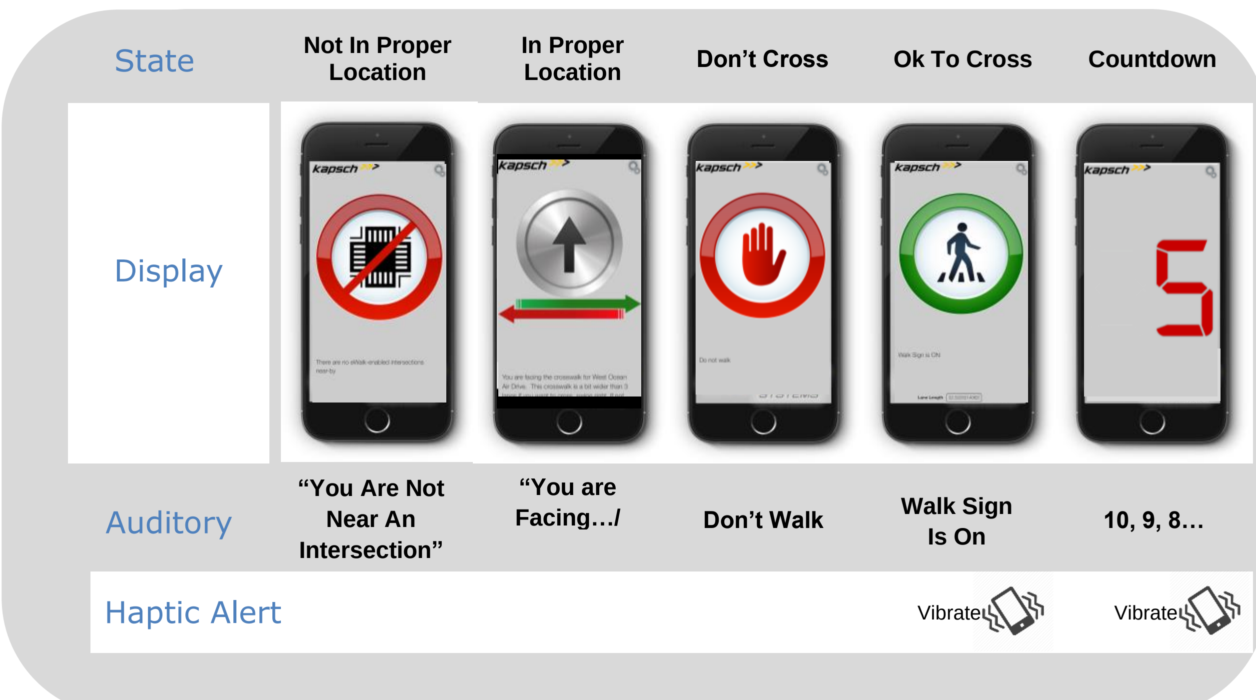


Figure 18: *eWalk Visual, Audio, and Haptic Messaging (Source: Kapsch)*

There are many potential benefits of this type of application, including:

1. Information for visually impaired. The information provided by Accessible Pedestrian Signals (APS) typically advise pedestrians when they have the right-of-way to cross at a signalized intersection. The information provided by the application goes well above and beyond that which typical APS devices can provide.
2. Continued guidance through a crosswalk: APS devices are not always effective at continued guidance through a crosswalk: audible cues are typically broadcast from the curbside, and typically only during the Walk phase and not during the clearance (flashing don't walk) phase. The additional information provided after the pedestrian leaves the curb, such as the clearance countdown and orientation in crosswalk warning, can be extremely valuable, and may be useful to sighted pedestrians as well.
3. No need to locate the pushbutton. While most pedestrian pushbuttons are conveniently located, some are not in an obvious location or are difficult to access. This can be particularly beneficial to pedestrians with limited mobility, parents with strollers, etc.
4. Ease in determining which crosswalk is being requested. While most modern pushbutton styles employ a tactile arrow to assist a pedestrian in determining which crosswalk the button serves, this is not the case for most legacy pushbuttons.
5. No need to touch infrastructure. This can help reduce the spread of germs, and was particularly recognized amid the COVID-19 outbreak.
6. Pedestrian presence is integrated into V2X applications and can be used to warn approaching drivers of the pedestrian presence in the crosswalk. While this can be useful for any pedestrian, it is of course particularly useful for those whose ability to monitor or react to approaching traffic is hindered in any way.
7. Capitalizes on multi-purpose equipment. The only equipment relied upon is the user's smart phone and the CV roadside equipment; while most APS solutions rely on single-purpose equipment.

Results

The City of Calgary Traffic Signals Engineering tested this application in the field in February 2020, Initial testing did not report pedestrian phase status as anticipated, however the issue was quickly isolated: a traffic controller firmware upgrade corrected the issue. It was later implemented and tested on 16 Avenue, and in June 2020 tested with a user group organized through the Canadian National Institute for the Blind (CNIB).

The user group responded that the application has excellent promise but is not ready for widespread deployment at this time. Extensive feedback was gained from this, with recommendations for an accessible pedestrian application:

Figure 19: *Users of this type of app will often use one hand for a cane or dog therefore have a need for hands-free capability*

- **Supplementary:** The application should not replace roadway infrastructure, as this relies on use of personal mobile devices. The focus of this application should be to further improve safety beyond APS devices, and to provide supplementary information and convenience to pedestrians.
- **Simple**: The application must be user-friendly.
- **Hands-free:** The application must allow verbal commands, and by default hands-free operation should be enabled.
- **Location accuracy reliance:** The application must not rely too heavily on very fine accuracy of smart phone GPS. Smart phone GPS may be reliable enough to locate a pedestrian close to an equipped intersection, but may not be not reliable enough to determine if and when a pedestrian is actually facing the desired crosswalk. It is better to give up some functionality (such as crosswalk orientation) than to mislead the pedestrian.
- **Concise:** If instructions are too wordy the application becomes cumbersome.
- **Specific:** The application must provide specific information. For example, a pedestrian should be informed which Walk light is on rather than simply that a Walk light is on.
- **Haptics**: touch-based cues may be useful but their purpose must be indicated to the user.
- **Battery consumption:** If battery drain is too high, pedestrians may not use the application.
- **Unsignalized crosswalks:** Support for crossing unsignalized crosswalks (such as channelized turns) should be included.

Project Outcomes

Stakeholder Engagement

The primary stakeholders engaged in this project were City of Calgary internal stakeholders. The City chose to engage stakeholders who would be directly involved in the installation and testing of the initial applications only. This was an intentional move meant to allow the appropriate time and space for testing and troubleshooting without complicating the project. Once established, further stakeholder engagement will be planned in order to capitalize on the test bed.

Stakeholders engaged included:

<u>The City of Calgary</u>

- Traffic Signals Engineering: the project proposal was formulated by and project management carried out by Traffic Signals Engineering.
- Traffic Management Centre: partnered in project delivery, from proposal through completion. TMC staff have been integral in the configuration and maintenance of equipment and supporting systems.
- Signals Maintenance & Construction: engaged in 2017 prior to project proposal. This group has provided essential support for all stages of the project, from RFP development to proponent selection to equipment installation and support. Signals Maintenance and Construction engagement has been maintained throughout the project with frequent meetings, emails, and phone calls.
- Calgary Fire Department: Representatives from the Calgary Fire Department and Roads Departments were engaged before the project was proposed in order to gain buy-in for the project itself. Initial engagement began on November 15, 2017. Once buy-in was gained, a CFD representative was appointed. Another engagement meeting with CFD was held on August 21, 2019 to review the intent of the project, schedule, installation and testing details, and answer questions posed by CFD. Engagement was maintained throughout the project through email and phone calls.
- Information Technology, Corporate Security: engagement is critical for network support, acceptance of the technology and cybersecurity measures; engagement and coordination is ongoing through meetings and email.
- Customer Service & Communications: engaged throughout the project to develop content for public engagement and to provide graphic design support.

The Canadian National Institute for the Blind

- Upon the decision to include testing of the eWalk application, CNIB was engaged through email initially, met on-site to conduct testing in June 2020, then met several times virtually to discuss testing results and compile feedback. Engagement has continued through email.

Product Vendors

Vendors have been engaged through close collaboration since award:

- Kapsch TrafficCom North America – OBE and RSE equipment, application, and technical support providers
- Blackberry Certicom – SCMS provider

Results Dissemination/ Recognition

Results have been periodically disseminated through:

- The City of Calgary website: articles posted to provide information to public, including https://www.calgary.ca/transportation/roads/traffic/traffic-management/connected-vehicle-pilot-project.html
  https://www.calgary.ca/general/smartcity/smart-stories.html
- Annual reports to Transport Canada
- CAVCOE (Canadian Automated Vehicles Centre of Excellence): project update October 2020
- ITS Canada Smart Mobility or Connected Infrastructure Award: Calgary Emergency Vehicle Corridor and eWalk Deployment
- Transportation Association of Canada Conference 2020: presentation and panel discussion as part of "Canadian CAV Pilot Deployments" panel

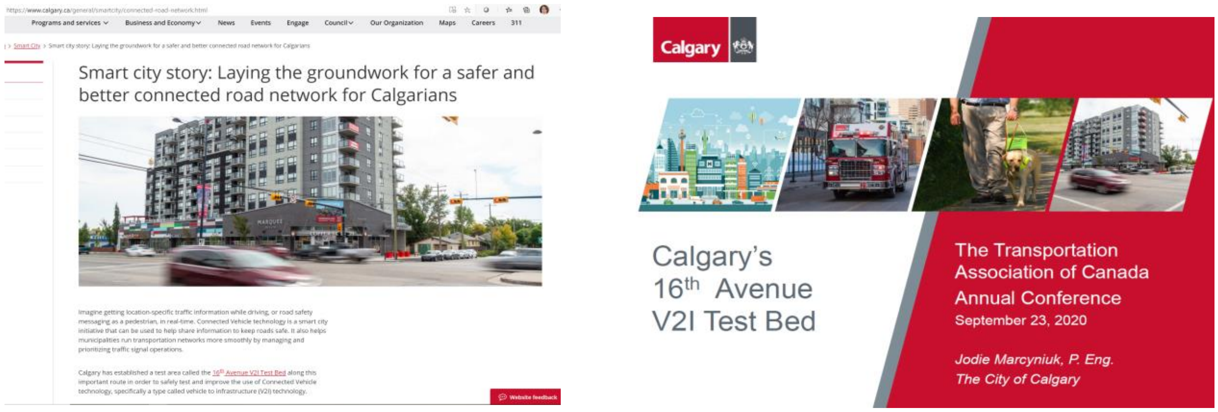


Figure 20: *Information Dissemination Samples – Web Content and TAC Presentation*

Equipment Installed and Operational

As of June 2021, equipment installed and operational consists of:

- 16 roadside units installed, with 15 currently operational. One unit (32 Avenue test location) is currently undergoing re-configuration.
- 14 intersections and one test site are covered. All 14 of these intersections are along 16 Avenue North, stretching from 14 Street West to Moncton/ Russet Road East.
- 4 Calgary Fire Department vehicles are instrumented with permanent installations, including the OBU and through-glass antenna. Additional units are utilized as portable temporary installations in test vehicles.

Figure 21: *Roadside Equipment Installation at Test Lab*

Conclusions

Benefits and Viability

The main benefits of V2X technology are road safety improvements, fuel and travel time savings, and improved network management. The pre-emption and eWalk applications specifically support road safety improvements. Kapsch V2X Assist supports road safety improvements as well as fuel savings. V2X management software such as Kapsch's CMCC supports management of devices and network management. Most importantly, the establishment of the test bed supports continued development and testing of use cases and systems.

This project proved that the environmental performance is viable in Calgary. Calgary's geographic location means that it is a windy but sunny city. Calgary is sandwiched between high elevation winds from the mountains, cold winds from the north and humidity from the south. Extreme temperature fluctuations are commonplace: high elevation winds offer respite from the bitter cold of winter but can wreak havoc on infrastructure. While the climate is relatively dry, this geography is ripe for extreme weather, thunderstorms, extreme snowfalls, and hailstorms tend to occur several times a year. While temperatures rarely exceed above +25C or below -25C, typically this will occur for several days of the year. Shortly after installation of the roadside equipment along 16 Avenue, we had the opportunity to witness the effect on extreme cold temperatures on performance. For 7 straight days in January 2020, daily highs were below -20C. Likewise, Calgary saw 9 straight days of -20C weather in February 2021. Calgary also experienced 8 straight days of temperatures over 27C in summer 2020. The equipment performed normally in both situations.

Viability was also proven in terms of functionality and performance. The tequipment and software largely performed as anticipated:

- V2X messaging was proven: SPaT, MAP, SRM, and SSM messaging were proven through various applications.
- The "V2X Assist" application, which combines several aspects of collision and red light warnings as well as information regarding signal phase status, has proven useful and will grow in benefit through uptake of CV technology.
- The emergency preemption application proved useful and, for the most part, reliable. However, this application is largely beneficial as a first step toward an integrated overarching multi-modal traffic signal application. This application is anticipated to continue to be used, as a measured improvement in response travel time was achieved.
- The eWalk application proved promising but challenges mean that until revisions are made, The City does not plan to continue to use this application.

- The CMCC management application proved very beneficial and viable in both configuration of devices and management thereof.
- The Blackberry SCMS was integrated successfully and proven to support pre-emption with certification and reject without it.

Challenges

Many challenges were faced through the course of this project. Several of the risks that were identified at the outset of the project were encountered. Of course, one challenge that was not anticipated was COVID-19. Overall, these challenges did not prove insurmountable, and the project was a success overall.

Scope creep: This was a risk that was identified at the outset, and indeed it manifested in several ways: outside parties approached The City for involvement in the project, and an application that was not planned for inclusion was proposed (eWalk).

> Although the eventual goal for the test bed is to partner with industry and academia, The City chose to avoid this involvement during initial stages of the project in order to avoid scope creep and to ensure that the project goals were met. The addition of eWalk to the project was made at the suggestion of Transport Canada and because of the anticipated low impact on the project budget. However, this scope creep was mitigated through appropriate signoff.

Lack of funds: the relative newness of the technology (especially within Canada) meant that budgeting was difficult. In this area, the project team was fortunate, especially in that Blackberry offered a trial version of their SCMS free of charge. Without this, the budget may have been at risk of overrun.

> The City had considered potential lack of sufficient funding and was prepared to respond by re-allocating funding, pursuing additional funding sources or partnerships, and revising scope as required.

Lack of time: it was anticipated that sufficient time was included in the project to make up for project delays. There were two significant impacts that resulted in schedule slippage: implementation of the SCMS, and the impact of COVID-10. Implementation of the SCMS did not proceed as smoothly as anticipated: initially there was difficulty establishing interoperability between the RSUs and OBUs. We encountered some delay coordinating equipment activation with SCMS implementation. We also encountered delay enrolling initially in the test environment, and again in the production environment. This also delayed further testing of the production environment between fire trucks and RSUs. However, given the reward of successfully securing our system with an SCMS, we believe that it has been worthwhile to incur this delay.

COVID-19 had a major impact on achieving the project goals within the schedule. The largest impact this had on the project schedule was with regards to scheduling of installation and testing of on-board units, as the Calgary Fire Department was enforcing strict rules regarding access to their facilities. Staff was less available to conduct troubleshooting and testing in-person, and engagement activities were limited or postponed.

Project delays were encountered and activities were not all completed by the originally planned dates. However, the project schedule allowed for adjustments to achieve the major project goals in time. Fortunately, most procurement, configuration, and installation activities had occurred before March 2020.

Lack of/ change in personnel resources: this was encountered to some degree. Some key members of the Kapsch and Blackberry teams were replaced during the course of the project. However, these members were replaced with competent members. The impact of COVID-19 led to some team members being unavailable in some capacity for portions of the project.

Availability of and change in personnel led to some need to ensure appropriate replacements, and to some project delay. This impact was not critical to the success of the project.

Inadequate or untimely materials, lack of quality: this was encountered to some degree. Some delay was faced in product delivery, particularly after COVID-19 impact. Equipment failure has not been encountered.

Quality was mitigated through careful scrutiny in several regards: requirements laid out in the RFP, interview process, and the Proof of Concept. Product supply requirements were laid out with award of the equipment supply contract.

Security vulnerability: There is a significant risk of vulnerability both on the side of road users and service providers without an SCMS or with an ineffective one. We chose not to include an SCMS in the Request for Proposal and to pursue this once the Proof of Concept had been established, in order to minimize delay and because the SCMS provider is a separate entity from the equipment provider.

The Blackberry SCMS was integrated in coordination with activation of the 16 Avenue Test Bed. While the intersections configured through the Proof of Concept were at risk until the time that the SCMS was integrated, only one of these was an active intersection, and activity there was monitored.

Evolution of Technology and Governance: this risk was not specifically outlined in the original project proposal and agreement, but was anticipated at the outset. At the time that the proposal was written, C-V2X was already gaining some traction as the potential communication means of choice for V2X technology. However, at the time, DSRC was the popular choice: it had been tested more thoroughly and was more readily available. The FCC mandated the V2X band to be used for C-V2X only, with a similar ruling anticipated in Canada.

The team chose to proceed by specifying DSRC, with the understanding that equipment replacement may be required. Furthermore, Kapsch made available their dual-mode roadside unit RIS-9260, which is capable of operating in either a DSRC or C-V2X mode. The City chose this option in order to futureproof our technology. OBE equipment will require replacement; however, limited OBE equipment has been deployed at this time.

Failure of software functionality as desired: This risk was identified to some degree under "lack of quality of materials", however another level of risk existed in the overall system functionality rather than the equipment, as well as with the added scope of the eWalk application.

While the emergency pre-emption application was proven to operate consistently through the Proof of Concept, a problem was encountered in the operation of the pre-emption de-activating and quickly re-activating before the vehicle arrives at the intersection. It was unknown if this was occurring during the Proof of Concept because it is only recognized if the vehicle arrives after the pre-emption is accepted and green had already served for the minimum duration. This is not normal for other forms of pre-emption, and so the suspected source was the signal request message. This is not necessarily a failure of the new equipment or software, and the source of the issue may reside elsewhere (such as within the traffic signal controller software).

The eWalk application did not perform as desired, as demonstrated through testing. While this proved a challenge, and the team worked together to address some of the concerns, ultimately the functionality of this application was not one of the main goals of this project.

Troubleshooting was carried out in an attempt to determine if the preemption functionality concern was a result of the V2X operation, the central traffic control system, or the traffic signal controller. To date this has been narrowed but not completely isolated. However, it was addressed by making allowances in the traffic signal programming to address the symptom of the problem instead: the traffic signal now must hold in the pre-emption phases long enough for the input to have a chance to re-initiate. The eWalk application will be renewed if concerns are addressed. Kapsch is currently planning updates to the app.

Opportunities and Next Steps

The primary goal of this project was to facilitate capacity-building, research and development, and innovation on CAV and transportation-related issues. Now that this test bed has been established, The City intends to maintain the test bed in order to further this goal. The planned next steps include:

- Testing of additional applications (internally and/ or in partnership with industry and academia). The same phased approach is intended, using our lab and beta testing locations through to the test bed. The City has several projects on the horizon where V2X solutions are being explored, such as goods movement and transit priority. It makes sense that these applications would be packaged and integrated into an MMITSS, which could balance these demands.
- Testing of alternative equipment and systems. This supports research and development, while also ensuring the best value to the public. Plans for this are underway, as The City has applied for participation in the Fortran Connected Intersection Challenge, which, if successful, will allow The City to pilot Fortran's V2X technology for a limited time.
- Transition to C-V2X. Following the FCC decision, The City anticipates a forthcoming similar decision by ISED. In anticipation of this, the team has begun to investigate transition to C-V2X.
- Continued involvement with national SCMS deployment and governance. The City has participated in workshops for a Transport Canada-sponsored national initiative to develop operating and governance models for a national SCMS.
- Adoption of technology, applications, and systems for permanent use. While the test bed is intended for testing of applications, they are expected to be maintained if found to be sufficiently beneficial. Engagement will continue with CFD to determine whether to maintain or remove DSRC equipment from emergency vehicles, or to replace with C-V2X equipment in order to maintain the existing benefit.
- Public engagement and integration of public devices. With increasing automotive industry commitment, and surging development in this field, we expect private connected vehicles to begin accessing the system. Because the Canadian SCMS is one shared national system, communication should occur seamlessly, regardless of the SCMS service provider the device subscribes to. This increasing public access can be capitalized on in terms of potential applications. However, this will result in a rush of big data that will need to be managed. The City will need to respond to increasing public demand for V2X technology.

Overall, the 16 Avenue North V2I Test Bed project has been a great success, and has spurred momentum for further testing and implementation within Canada. The City of Calgary has had the great privilege of benefiting from the ACATS program, and we look forward to continuing to pursue and support this important technology.

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